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2009 Fishes Annual Status and Trends Report for the San Francisco Estuary

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Introduction

The 2009 Status and Trends fishes report includes data from 5 of the Interagency Ecological Program's long-term fish monitoring surveys in the San Francisco Estuary: 1) the Summer Townet Survey (TNS), 2) the Fall Midwater Trawl Survey (FMWT), 3) the San Francisco Bay Study (Bay Study), 4) the Delta Smelt 20-mm Survey (20-mm Survey), and 5) the U.S. Fish and Wildlife Service (USFW) Beach Seine Survey (see Honey et al. 2004 for additional fish surveys). The most recent abundance indices, long-term abundance trends, and distributional information are presented for the most common species in the estuary and some less-common species of interest, such as delta smelt, splittail, and the surfperches. Presented first are 4 pelagic species that spawn and rear in the upper estuary and have undergone severe declines in recent years (Sommer et al. 2007). The upper estuary demersal fishes, marine pelagic fishes, surfperches, and marine demersal fishes follow this group. Within each section, species are presented phylogenetically.

Methods

We used several physical data sets to describe ocean and estuary environmental conditions. Daily outflow at Chipps Island from the Department of Water Resources (DWR) Dayflow computer program was used to calculate all outflow values: the 2009 daily values were plotted and the 1979-2009 daily values averaged by month and plotted. The daily estimated distance in river kilometers from the Golden Gate to 2 parts-per-thousand salinity, as X2, was also from the Dayflow program. Monthly Pacific Decadal Oscillation (PDO) indices were from Nathan

1. Authorship: Introduction, Methods, and Physical Setting, K. Hieb; American and threadfin shad, and longfin smelt, D. Contreras; delta smelt, striped bass, and splittail, V. Afentoulis; the gobies, flatfishes, plainfin midshipman, and Pacific staghorn sculpin, M. Fish; Pacific herring, northern anchovy, jacksmelt, the surfperches, and white croaker, J. Messineo.

Mantua (University of Washington) and plotted for 1950-2009. North Pacific Gyre Oscillation (NPGO) indices were from Emanuele Di Lorenzo (Georgia Institute of Technology) and were plotted for 1950-2009. Daily ocean upwelling indices and monthly anomalies (base period 1946-1967) from 39°N were from the National Marine Fisheries Service (NMFS) Pacific Fisheries Environmental Laboratory. The monthly anomalies were plotted from 1999-2009. A daily Cumulative Upwelling Index (CUI) was calculated for 2007, 2008, 2009, and 1967-2009 (the period of daily data) per Bograd et al. (2009). The spring transition, which is the start of the upwelling season, is the date of the minimum CUI. We used the CUI inflection points to identify the length of the upwelling period as well as strong upwelling and relaxation events. Daily sea surface temperatures (SSTs) were from Southeast Farallon Island (Scripps Institute of Oceanography); monthly values and anomalies were calculated from the daily values, and we used 1925-2009 as the base period for the anomalies. Daily SSTs from January 2008 to December 2009 and monthly anomalies from 1999-2009 were plotted. See "Notes" for the data download URLs.

The TNS has been conducted annually since 1959, and its data has been used to calculate age-0 striped bass indices for all years except 1966, 1983, 1995 and 2002. In addition, age-0 delta smelt indices have been calculated for the period of record, except for 1966-1968. The TNS currently begins in June and samples 32 sites from eastern San Pablo Bay to Rio Vista on the Sacramento River and Stockton on the San Joaquin River. Historically the number of surveys ranged from 2 to 5 each year; beginning in 2003, sampling was standardized to 6 surveys per year, starting in early June and running every other week through August. The striped bass index is an interpolation between the survey indices from the 2 surveys that bracket when age-0 striped bass reach or surpass 38.1-mm fork length (FL) mean size (Chadwick 1964, Turner and Chadwick 1972). The delta smelt index is the average of the first 2 survey indices.

The FMWT has sampled annually since 1967, except 1974 and 1979, when no surveys were conducted, and 1976, when sampling was limited and indices were not calculated. The FMWT was initiated to determine the relative abundance and distribution of age-0 striped bass in the estuary, but its data is used for other upper-estuary pelagic species, including American shad, threadfin shad, delta smelt, longfin smelt and splittail. The FMWT survey samples 116 stations monthly from September to December in an area ranging from San Pablo Bay to Hood on the Sacramento River and to Stockton on the San Joaquin River. The index calculation (Stevens 1977) uses catch data from 100 of these 116 stations; the remaining 16 stations were added to increase spatial coverage for delta smelt in 1992.

The Bay Study has sampled from South San Francisco Bay (South Bay) to the western delta monthly with an otter trawl and midwater trawl since 1980. There are data gaps in this long-term sampling, most significantly limited midwater trawl sampling in 1994, no winter sampling from 1989 to 1997, and limited sampling at stations in and near the confluence of the Sacramento and San Joaquin rivers in 2007 and 2008 to reduce delta smelt take. This most recent data gap resulted in no Bay Study delta smelt indices for 2007 and 2008. Abundance indices are routinely calculated for 35+ fishes and several species of crabs and caridean shrimp. Only the most common fish species are included in this report; the crabs and shrimp are subjects of separate annual reports. Of the 52 stations the Bay Study currently samples, 35 have been consistently sampled since 1980 ("core" stations) and are used to calculate the annual abundance indices. Additional information about study methods, including index calculation, can be found in IEP Technical Report 63 (Baxter et al. 1999).

The 20-mm Survey monitors larval and juvenile delta smelt distribution and relative abundance throughout their historical spring range, which includes the entire delta downstream to eastern San Pablo Bay and the Napa River. Surveys have been conducted every other week from early March into July since 1995, with 9 surveys completed in 2009. Three tows are completed at each of the 48 stations using a 1,600-μm mesh net (Dege and Brown 2004). The survey name is derived from the size (20 mm) at which delta smelt are readily identifiable and counted at the State Water Project and Central Valley Project fish facilities.

United States Fish and Wildlife Service has conducted beach seine sampling weekly since 1992 at approximately 40 stations in the delta and the Sacramento and San Joaquin rivers upstream of the Delta (Brandes and McLain 2001). Data from 33 stations ranging from Sherman Lake at the confluence of the Sacramento and San Joaquin rivers upstream to Ord Bend on the Sacramento River, and to Stockton on the San Joaquin River was used to calculate the annual age-0 splittail abundance index. Stations were grouped into 8 regions and the index was calculated as the sum of regional mean catch per seine haul for May and June sampling.

We used data sets from the TNS, FMWT, and Bay Study to describe abundance trends and distribution of upper estuary pelagic fishes when available, while only Bay Study midwater trawl (BSMWT) data was used for the marine pelagic fishes and Bay Study otter trawl (BSOT) data for demersal fishes. Two data sets provided only single species indices: the 20-mm Survey data for delta smelt larvae and small juveniles and the USFWS beach seine data for age-0 splittail. Catch-per-unit-effort (CPUE), reported as catch per tow, was consistently used to analyze and report distribution.

Physical Setting

Delta outflow was again very low in 2009, with a mean January to June monthly outflow at Chipps Island of 395 cubic meters per second (cm/s). This was comparable to 2008 and slightly higher than 2007 for the same period. The 3 consecutive low outflow years from 2007-2009 were the longest period of low outflow since the 1987-1992 drought (Figure 1). There were 2 outflow peaks in 2009, one from mid-February to mid-March that averaged approximately 1,000 cm/s per day and one in early May that averaged about 600 cm/s over 2 weeks (Figure 2). This first outflow event maintained X2 just upstream of Roe Island in eastern Suisun Bay (river kilometer 68) and resulted in the lowest salinities of the year in the upper estuary. X2 quickly moved upstream to Chipps Island (river kilometer 75) in April, briefly moved downstream again to near Roe Island (river kilometer 70) in mid May, and then steadily moved upstream from late May through the remainder of the water year.

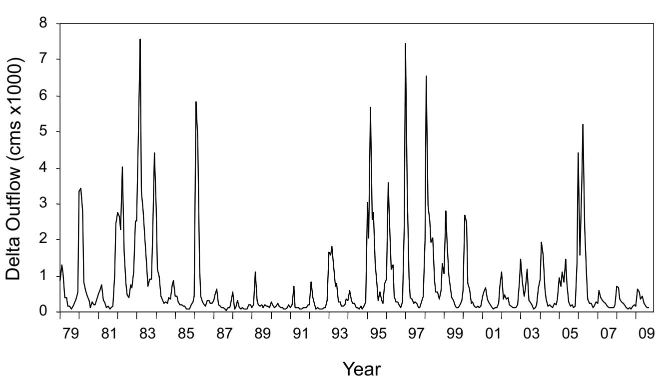

Figure 1 Mean monthly Delta outflow (cms) at Chipps Island, 1979-2009.

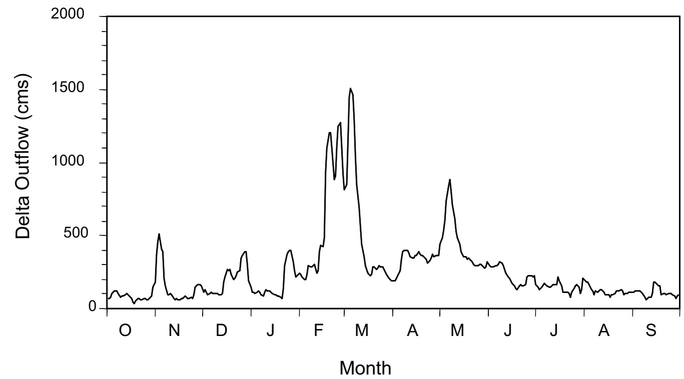

Figure 2 Daily Delta outflow (cms) at Chipps Island, October 2008 to September 2009.

The San Francisco Estuary is situated between 2 major marine faunal regions, the cold-temperature fauna of the Pacific Northwest and the subtropical fauna of southern and Baja California, and is a transitional area with elements of both faunal groups (Parrish et al. 1981). The northern Pacific Ocean reportedly entered a cold-water regime in 1999 (Peterson and Schwing 2003), which is hypothesized to be beneficial to many cold-temperate species, including Dungeness crab, English sole, and many of the rockfishes. This most recent cold-water regime was preceded by a warm-water regime from 1977 to 1998, which resulted in increased abundance of subtropical species in San Francisco Estuary, including California halibut, white croaker, Pacific sardine, and California tonguefish.

The Pacific Decadal Oscillation (PDO) and North Pacific Gyre Oscillation (NPGO) are 2 indices of basin-scale ocean climate conditions. A positive PDO index is most strongly associated with warmer ocean temperatures, a stronger Alaska Current, and a weaker California Current, while a positive NPGO index is associated with increased salinity, upwelling, nutrients, and primary production and a stronger California Current (Di Lorenzo et al. 2008, Di Lorenzo et al. 2009). Major ecosystem regime shifts have occurred in the North Pacific when the PDO and NPGO show strong, simultaneous and opposite sign reversals, such as in 1999 (Di Lorenzo et al. 2008). During cold-water regimes, the PDO indices are generally negative and the NPGO indices positive (Figures 3A and 3B), with frequent La Niña events. Warm-water regimes have positive PDO indices and negative NPGO indices, with frequent and strong El Niño events. The most recent cold-water regime is not unprecedented, but appears to be the strongest in the past 60 years based on the NPGO indices.

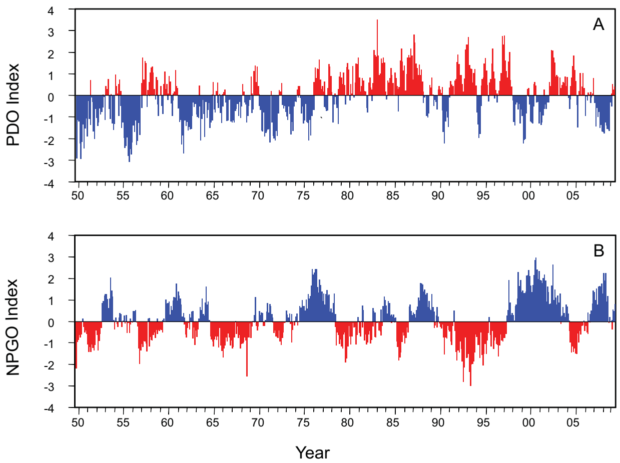

Figure 3 A. Monthly Pacific Decadal Oscillation (PDO) indices, 1950-2009 and B. Monthly North Pacific Gyre Oscillation (NPGO) indices, 1950-2009.

From summer 2007 through early 2009, there was a La Niña event in the tropics, resulting in negative PDO indices and positive NPGO indices (Figures 3A and 3B). Spring 2009 was neutral, but an El Niño event developed in summer 2009 and continued through early 2010 in the tropics. El Niño or other warm water events during a cold-water regime are not unusual. Within the past decade, there were 3 other El Niño events of 6 to 11 months in duration from summer 2002 to early 2007. Not all were apparent along the Central California coast, but we did observe many months of above average SSTs and reduced upwelling from late 2002 through 2006 (Figures 4A and 4B). The warmest SSTs of the past decade in the Gulf of the Farallones (GOF) were in 2005 and 2006. There is often a time delay between the appearance of La Niña and El Niño events in the tropics and effects along the Central California coast, and not all tropical events manifest similarly at this latitude.

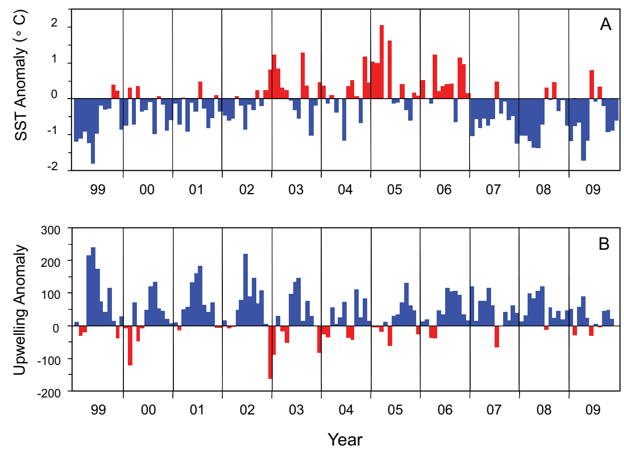

Figure 4 A. Monthly Sea Surface Temperature (SST, °C) anomalies from Southeast Farallon Island, 1999-2009 and B. Monthly upwelling index anomalies (39°N), 1999-2009.

Gulf of the Farallones sea surface temperatures (SSTs) were about 1°Celsius (C) cooler than the long-term mean in late 2008 and early 2009 (Figure 4A), when many marine fishes that rear in San Francisco Estuary spawn in coastal waters. Sea surface temperatures decreased even further in April and early May 2009 and were almost 2°C cooler than the long-term mean. April 2009 had the second coldest SSTs for the month in the period of record (1925-2009), with a mean daily SST of 9.6°C, while May had alternating periods of SSTs just below and above 10°C (Figure 5). In June, concurrent with the El Niño that developed in the tropics, ocean temperatures suddenly increased in the GOF to above 14°C (Figure 5); the June monthly mean SST was almost 1°C warmer than the long-term mean (Figure 4A). Although the El Niño event continued in the topics through late 2009, SSTs in the GOF were near the long-term mean from July through September and then about 1°C cooler from October through December. SSTs are typically at their annual maximum in fall; in late September and early October 2009, daily SSTs reached 14°C briefly and then remained above 13°C for about 3 weeks (Figure 5).

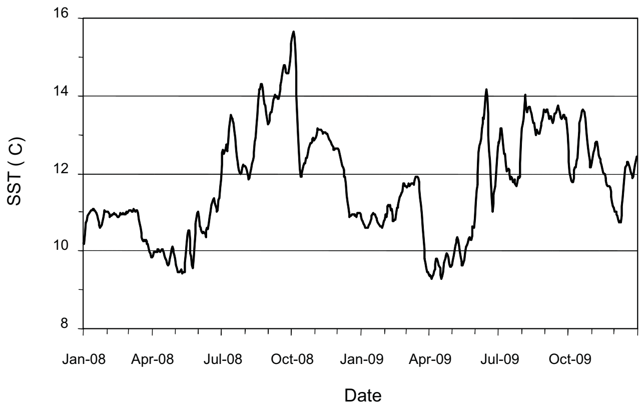

Figure 5 Daily Sea Surface Temperature (SST, °C) from Southeast Farallon Island, January 1, 2008 to December 31, 2009.

The coastal ocean along central California is marked by 3 seasons: the upwelling season, from spring to late summer; the oceanic season, from late summer to late fall; and the Davidson Current season, from late fall to spring. During the upwelling season, prevailing northwesterly winds result in a southward surface flow, known as the California Current. Due to the Earth's rotation and the Coriolis Effect, there is a net movement of surface waters offshore. These waters are replaced by nutrient-rich, cold water that is transported or upwelled from deeper areas. Upwelling is responsible for the high productivity of the California Current System. When the winds weaken in fall, upwelling stops, surface coastal waters warm, and productivity declines. In winter, southwesterly winds result in a northward surface flow, or the Davidson Current. This current, in conjunction with the Coriolis Effect, produces an onshore and downward transport of surface water, or downwelling. Many coastal fish and invertebrate species in the California Current Region reproduce in winter during the Davidson Current season, when pelagic eggs and larvae are likely to be transported to or retained in nearshore areas. Juveniles of most species settle to the bottom nearshore and enter estuaries to rear before the onset of upwelling, because pelagic life stages present during the upwelling season will be transported offshore, often far from their preferred nearshore nursery areas.

Coastal upwelling, as indicated by the monthly anomalies from near the San Francisco Estuary, was strong through early May 2009, relatively weak from late May through August with the onset of the El Niño event, then stronger than average from September on (Figure 4B). The strong upwelling in April and early May was associated with the coolest SSTs of the year. From the minimum point of the daily Cumulative Upwelling Index (Figure 6), the 2009 spring transition was in early March, which was close to the norm for this latitude. For much of the last decade, winter upwelling has been relatively strong and the spring transition has been early. For example there was strong early winter-spring upwelling and an early spring transition in 2007 and 2008 (Figure 6), although the early season upwelling was strong in January, March, and April of 2007 and March and April of 2008.

These conditions should have been favorable for primary and secondary production in the GOF in late winter-early spring 2009, but weak upwelling after early May may have hindered productivity. Several seabirds had very poor reproductive success at the Farallon Islands in 2009, most likely due to low prey abundance during the chick-rearing period (Warzybok and Bradley 2009). Euphausiids were abundant but forage fishes, such as, anchovy, sardine, and juvenile rockfish were largely absent in the GOF. The very poor foraging conditions resulted in reduced breeding success, reduced breeding effort, and increased adult mortality for the fish-eating birds, such as Brandt's Cormorants, Common Murres, Western Gulls, and Rhinoceros Auklets (Warzybok and Bradley 2009).

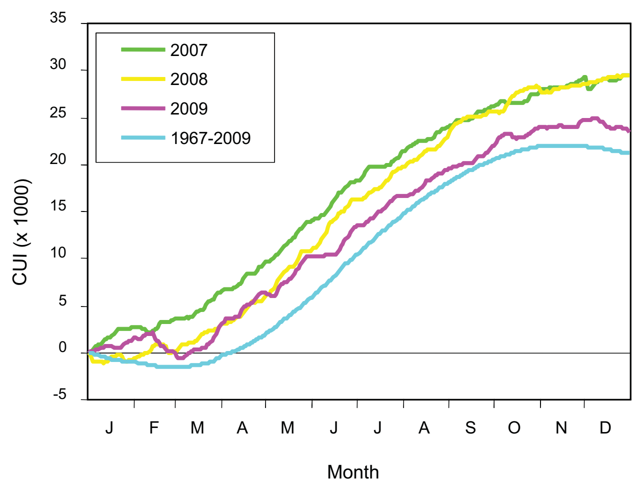

Figure 6 Daily Cumulative Upwelling Index (CUI, x 1,000) for 2007, 2008, 2009, and averaged for 1967-2009.

Upper Estuary Pelagic Fishes

American shad

The American shad (*Alosa sapidissima)* was introduced into the Sacramento River in 1871 and is now found throughout the estuary. This anadromous species spawns in rivers in late spring, rears in fresh water through summer (including the delta starting in late May), and migrates to the ocean in late summer and fall. It spends approximately 3 to 5 years maturing in the ocean before returning to freshwater to spawn. Most males reach maturity within 3 to 4 years of age, while most females reach maturity within 4 to 5 years of age. Spawning occurs in the Sacramento, Feather, and American rivers from April through June, after which a large percentage of adults die (Stevens 1966). All life stages of American shad are planktivores.

The 2009 FMWT American shad (all ages) index was 2.3 times the 2008 index, and the fourth lowest index on record (Figure 7A). With the exception of the record high index in 2003, indices have been below the study-period mean since 1998. American shad were collected in all areas of the upper estuary in 2009, but were most abundant from Suisun Bay to the lower Sacramento River. They were most common in the lower Sacramento River in September and October, the lower Sacramento River through Suisun Bay in November, and Suisun Bay in November and December.

The 2009 BSMWT age-0 American shad index was also substantially higher than the 2008 index, yet was well below the study mean (Figure 7B). The BSMWT collected age-0 American shad from July through December, and abundance peaked in August. They were collected from San Pablo Bay to the lower Sacramento and San Joaquin rivers and were most common in the lower rivers. The largest single catch occurred during August in the San Joaquin River at the Santa Clara Shoal station.

The American shad index increased for both surveys from 2008 to 2009. However, abundance remained relatively low for both surveys, which may have resulted from the relatively low spring outflow in 2009. American shad abundance has shown a positive correlation with delta outflow during the spring spawning and early rearing period (Figure 8; Stevens and Miller 1983). For unknown reasons this response was enhanced after the introduction of the overbite clam, *Corbula amurensis*, in the late 1980s (Kimmerer 2002). During the POD years (2001-2009) abundance was more variable and the outflow-abundance relationship became steeper (Figure 8).

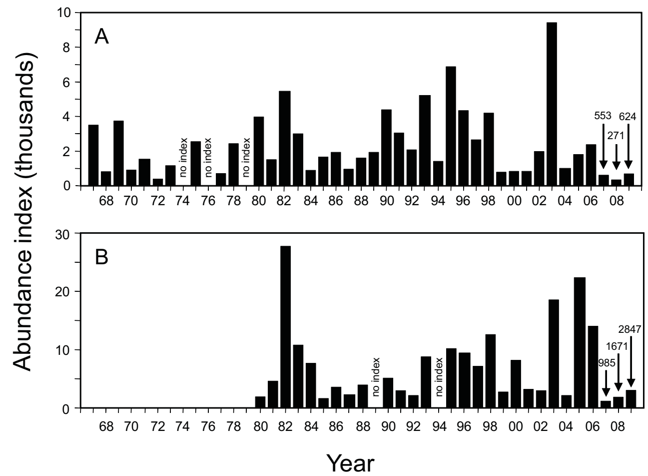

Figure 7 Annual abundance of American shad: A) FMWT, all sizes, September-December, B) Bay Study midwater trawl, age-0, July-October.

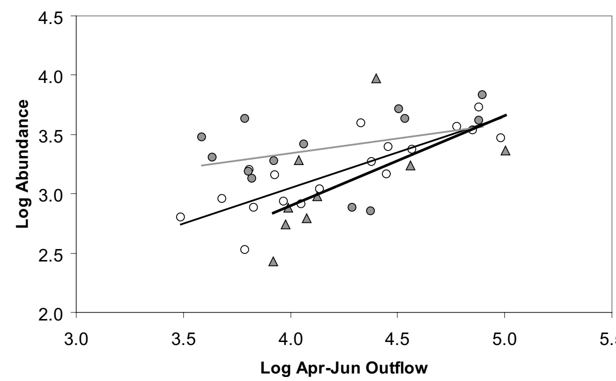

Figure 8 Fall Midwater Trawl American shad annual abundance indices (all ages; dominated by age-0 fish) plotted on April through June mean monthly Delta outflow (cfs), both variables Log^{10} transformed (update of CDFG 1987). Relationships depicted are pre-*Corbula amurensis* (1967-1987; open circles, black line) and post-*C. amurensis* (1988-2000; filled circles, grey line) and more recent years during the Pelagic Organism Decline (POD) (2001-2009; grey triangles, thick black line). Lines indicate significant relationships, $p<0.05$.

Threadfin Shad

The threadfin shad (*Dorosoma petenense*) was introduced into reservoirs in the Sacramento-San Joaquin watershed in the late 1950s and quickly became established in the delta. Although it is found throughout the estuary, it prefers oligohaline to freshwater dead-end sloughs and other low-velocity areas (Wang 1986). It is planktivorous its entire life, feeding on zooplankton and algae (Holanov and Tash 1978). Threadfin shad may reach maturity at the end of their first year and live up to 4 years. Spawning occurs in late spring and summer and peaks from May to July (Wang 1986).

The 2009 FMWT threadfin shad (all ages) index was 10% of the 2008 index (Figure 9) and by far the lowest index on record. Since 2002, threadfin shad abundance has been below average, but showed a slight increasing trend through 2007 before dropping off precipitously. The threadfin shad catch increased from September through December and fish were caught from Carquinez Strait through the lower Sacramento River and from the south delta. They were most abundant in the lower Sacramento River.

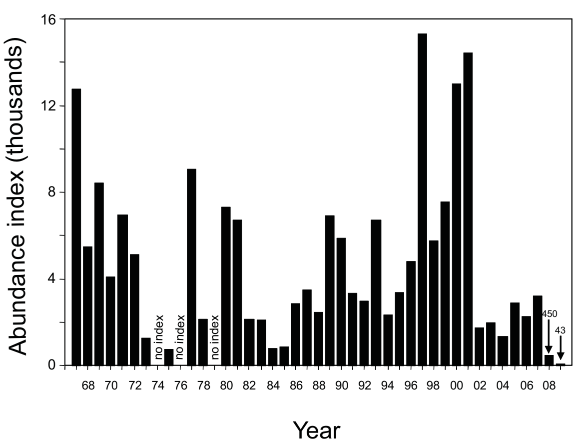

Figure 9 Annual abundance of threadfin shad (all sizes), FMWT, September-December.

Delta smelt

The delta smelt (*Hypomesus transpacificus*) is a small (55-90 mm FL) osmerid endemic to the upper San Francisco Estuary. The delta smelt population declined dramatically in the 1980s and it was listed as a state and federal threatened species in 1993. This species is considered environmentally sensitive because it typically lives for one year, has a limited diet, and resides primarily in the interface between salt and fresh water. In addition, females have low fecundity and produce on average 1,200 to 2,600 eggs (Moyle et al. 1992).

In 2009, delta smelt abundance declined in all surveys, except in the BSMWT. The 2009 20-mm Survey delta smelt index declined 21% from the 2008 index (Figure 10A), and was the second lowest index on record. Delta smelt larvae were first collected in March in Honker Bay and the lower Sacramento River. By April, larvae were broadly distributed within the delta, from the Cache Slough complex, and Sacramento Deep Water Ship Channel, to the lower San Joaquin River and within the central and southern delta (Middle and San Joaquin rivers). In May, the distribution of juvenile delta smelt expanded downstream into the western portion of Suisun Bay. By June, juvenile delta smelt were no longer being caught in Suisun Bay, but remained distributed from the confluence and the lower San Joaquin River upstream through the lower Sacramento River and into the Cache Slough complex and the Sacramento Deep Water Ship Channel. By the conclusion of the survey in late-June into July, juvenile delta smelt were mainly caught in the lower Sacramento River with a second concentration of fish caught in the Cache Slough and Sacramento Deep Water Channel region and an individual fish in western Suisun Bay.

The 2009 TNS age-0 delta smelt index declined 50% from the 2008 index (Figure 10B) and equaled that of 2005, the lowest index on record. Delta smelt TNS catch totals in 2009 were bimodal, peaking in early June with a catch of 11 and then again in early August with a catch of 10 fish. This was similar to the pattern observed in 2008, when peaks occurred in early June and the middle of July. In summer 2009, delta smelt were distributed from Carquinez Strait to the lower Sacramento and San Joaquin rivers. Delta smelt were similarly dispersed in summer 2008. Also similar to 2008, the catches in 2009 tended to be slightly higher in Honker Bay and lower Sacramento River than in other areas. In early June 2009, the delta smelt catch was greatest in Montezuma Slough and the lower Sacramento River, with individual fish caught in Broad Slough and the lower San Joaquin River. By early July, delta smelt catches only occurred in Grizzly Bay and the lower Sacramento River. By the end of July, the catches extended from Suisun Bay through the confluence and into the lower Sacramento River. In August, the majority of fish were collected near Honker Bay.

The 2009 BSMWT age-0 delta smelt index was 142, relatively low compared to historical abundance (Figure 10C). In 2007 and 2008, the Bay Study did not report an age-0 delta smelt index because midwater trawl sampling bypassed several stations where delta smelt catch might have been high. The index in 2006 was 0. In 2009, most age-0 delta smelt were distributed from Honker Bay to the lower Sacramento River. Delta smelt are not effectively sapled by the BSOT, so these data are not reported.

The 2009 FMWT delta smelt index declined 26% from the 2008 index and was the lowest on record (Figure 10D). In September of 2009, delta smelt were collected only in western Montezuma Slough and Suisun Bay. October and November catches were similar with delta smelt found in Suisun Bay, but with the added expansion upstream into the lower Sacramento River. In October, delta smelt were also present in Cache Slough. In December 2009, catches broadened downstream in the Suisun Bay region especially near Honker bay, and a few were caught in the confluence and lower Sacramento River areas.

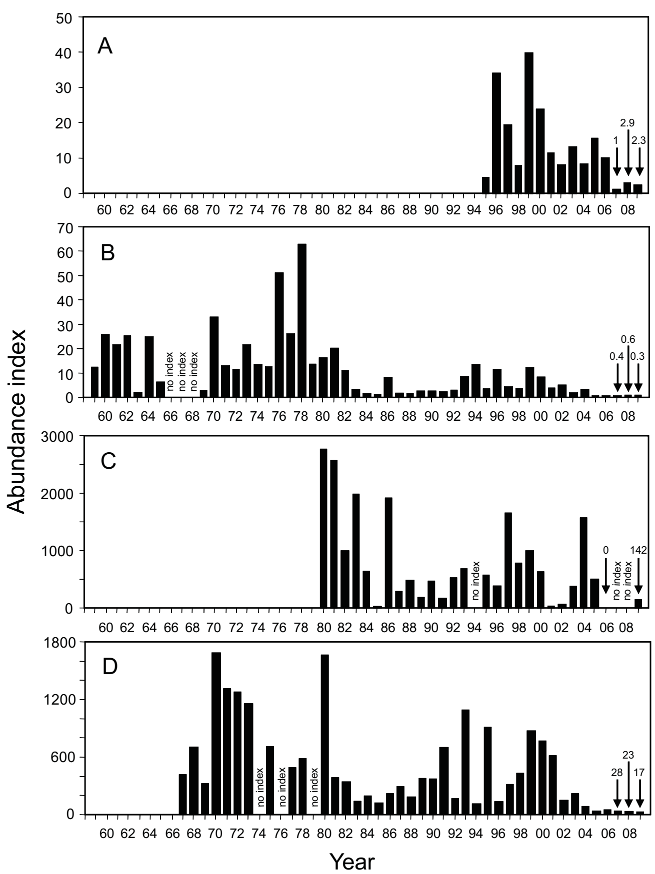

Figure 10 Annual abundance of delta smelt: A) 20-mm Survey larvae and juveniles, based on 4 surveys bounding 20 mm mean length; B) TNS, age-0, mean of survey 1 and 2 abundance indices; C) Bay Study midwater trawl, age-0, June-October; D). FMWT, all sizes, September-December.

Longfin smelt

The longfin smelt (*Spirinchus thaleichthys*) is a short-lived anadromous species that spawns in freshwater in winter and spring and rears primarily in brackish water. Some age-0 and age-1 fish migrate to the ocean in summer and fall, often returning to the estuary in late fall of the same year. A few longfin smelt mature at the end of their first year and most at the end of their second year, with some living to spawn or spawn again at age-3 (Wang 1986). A strong positive relationship between longfin smelt abundance and winter-spring outflow has long been observed (Stevens and Miller 1983). However, this relationship changed in the late 1980s, after the introduction of the overbite clam, *C. amurensis*. Although the slope of the outflow-abundance relationship did not change appreciably, longfin smelt abundance post-*C. amurensis* declined to a fraction of the pre-*C. amurensis* abundance. This decline corresponded with a decline in phytoplankton and zooplankton abundance, which has been attributed to grazing by *C. amurensis* (Kimmerer 2002). A similar downward shift of the longfin smelt outflow-abundance relationship occurred after 2000, during the Pelagic Organism Decline years (Sommer et al. 2007, Fish et al. 2009).

The 2009 FMWT longfin smelt (all ages) index was 47% of the 2008 index and the second lowest on record (Figure 11A). Longfin smelt began migrating upstream into Suisun Bay in October. By December, they were found from San Pablo Bay through the lower Sacramento and lower San Joaquin rivers. Through the entire September through December period, longfin smelt were most commonly caught in Suisun Bay.

The 2009 BSMWT age-0 longfin smelt index was 27% of the 2008 index and the third lowest in the study period (Figure 11B). The BSMWT collected age-0 fish sporadically through the year: a few each in May, August, and December. Age-0 longfin smelt were collected from South Bay upstream into the lower Sacramento River, except in Central San Francisco Bay (Central Bay), with the highest catches occurring in Suisun Bay.

The 2009 BSOT age-0 longfin smelt index was 16% of the 2008 index (Figure 11C), an abundance decrease similar to that of the BSMWT. Age-0 fish were collected from June through December and abundance peaked in July. They were collected from South Bay through Suisun Bay, but were most common in Central Bay during most months, quite different from BSMWT results.

All 2009 longfin smelt abundance indices decreased in response to the low winter/spring outflow. The FMWT longfin smelt abundance-outflow relationship shifted downward after the introduction of *C. amurensis* and again in the POD years, 2001-2009 (Figure 12). The 2009 index was below the regression line for the post-*C. amurensis* abundance-outflow relationship. This year's decrease in abundance also may be attributed, in part, to the weak 2007-year class, the parents of the 2009-year class. Mac Nally and others (2010) described the FMWT longfin smelt abundance trend as a long-term decline punctuated by abundance increases associated with high outflow periods and they too detected that abundance was most significantly influenced by outflow.

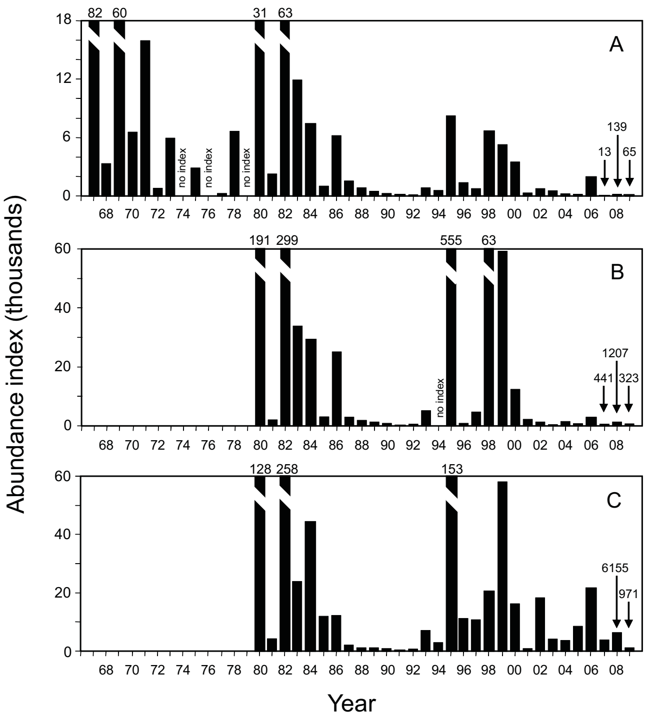

Figure 11 Annual abundance of longfin smelt: A) FMWT (all ages), September-December; B) Bay Study midwater trawl, age-0, May-October; C) Bay Study otter trawl, age-0, May-October.

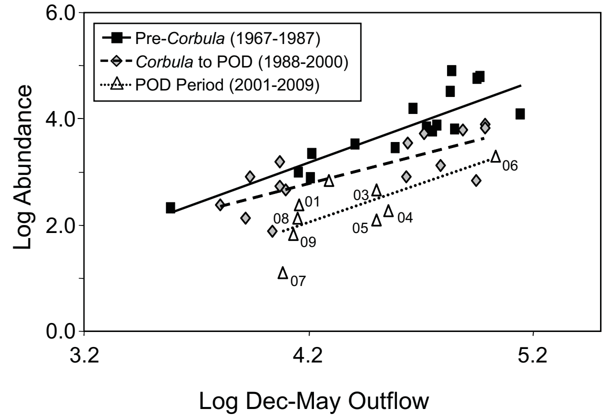

Figure 12 FMWT age-0 longfin smelt annual abundance (all ages) index plotted on December through May mean monthly Delta outflow (cfs), both variables Log_{10} transformed. Relationships depicted are pre- *Corbula amurensis* (1967-1987; black squares, solid line) and post *C. amurensis* (1988-2000; grey diamonds, dashed line) and POD years (2001-2009, open triangles, dotted line). Lines indicate significant relationships, $p < 0.05$.

The clam *C. amurensis*, through its affect on the food web, appears to have affected longfin smelt distribution. Longfin smelt distribution in the FMWT shifted towards higher salinity waters after 1989, a few years after *C. amurensis* was introduced, and this pattern has remained consistent since (Figure 13). This suggests that *C. amurensis* displaced longfin smelt through a reduction in food availability, similar to that proposed for the northern anchovy (*Engraulis mordax*) distribution shift downstream reported by Kimmerer (2006). The longfin smelt diet once contained a high proportion of the mysid, *Neomysis mercedis* (Freyrer et al. 2003). The decline of *N. mercedis* also has been attributed to competition for food with *C. amurensis* (Kimmerer and Orsi 1996). One study found that *Neomysis* spp. primarily fed on diatoms, rotifers, and copepods (Siegfried and Kopache 1980), food resources shared with *C. amurensis* (Kimmerer and Orsi 1996). Longfin smelt may have displaced to higher salinity areas to find food sources not impacted by *C. amurensis*.

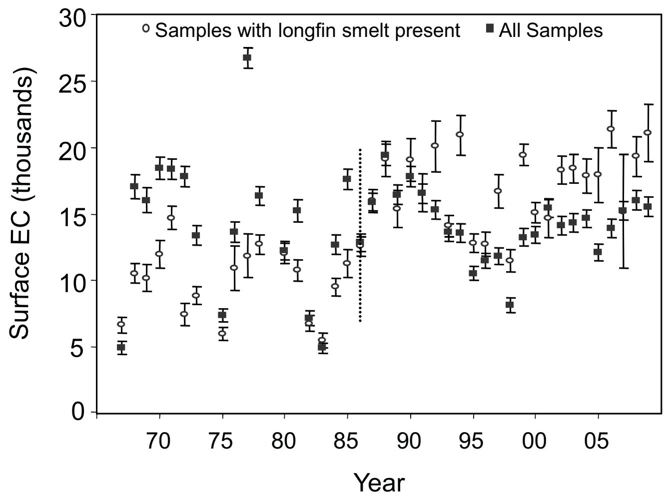

Figure 13 Mean (± 1 SD) surface water electrical conductivity (EC) for FMWT samples with longfin smelt present (open circles) and all samples (black squares). Dotted line represents the year *C. amurensis* was discovered in the San Francisco Estuary.

Splittail

The splittail (*Pogonichthys macrolepidotus*) is endemic to the San Francisco Estuary and its watershed. Adults migrate upstream from tidal brackish and freshwater habitats during increased river flows from late fall through spring to forage and spawn on inundated floodplains and river margins (Sommer et al. 1997, Moyle et al. 2004). Such migrations are known to occur in the Sacramento, San Joaquin, Cosumnes, Napa and Petaluma rivers, as well as Butte Creek and other small tributaries. Most spawning takes place from March through May. Young disperse downstream as larvae, when river levels drop or as juveniles in late spring and early summer, when backwater and edge-water habitats diminish with reduced flows. Year-class strength is related to the timing and duration of floodplain inundation; moderate to large splittail year classes resulted from inundation periods of 30 days or more in the spring months (Sommer et al. 1997, Moyle et al. 2004).

Age-0 splittail may not be effectively sampled by long-term monitoring surveys employing trawling that requires fishing in open, moderately deep (= 2 m) water, because young splittail possess a strong affinity for shallow water. The USFWS Delta Juvenile Fish Monitoring Program conducts an annual beach seine survey and can calculate an abundance index for age-0 splittail. In addition to sampling along the shoreline, this survey samples throughout the delta and upstream on the Sacramento River to Colusa (see methods), so it is able to detect recruitment upstream in the rivers. The beach seine index was not updated for 2008 until this year. The 2009 age-0 splittail beach seine index as reported by the USFWS was 62.4, an increase (36%) from the 2008 abundance index of 45.8. The range of index values since 2007 were an order of magnitude less than those of the 4 prior years were. Both the highest and lowest abundances (in 2006 and in 2002, respectively) have been recorded in the last 10 years (Figure 14A). The variability of the age-0 splittail abundances likely reflects the variability in outflows in recent history.

The BSMWT collected no age-0 splittail in 2009, resulting in 9 consecutive years with very low or 0 indices (Figure 14B). No age-0 splittail were collected in 2009 by the BSOT, resulting in a zero index for the 3rd consecutive year (Figure 14C). The 2009 FMWT splittail (all ages) index was 1 (Figure 14D). This is following a 2008 index of 0 and 6 prior years of very low indices.

Age-0 splittail were virtually not detected by trawl surveys in 2009, but there was some evidence of splittail recruitment from the USFWS beach seine sampling. Aasen (page 72, this issue) reported some, but low splittail salvage for 2009 for both state and federal fish salvage facilities; typically, salvage is dominated by age-0 fish (Moyle et al. 2004).

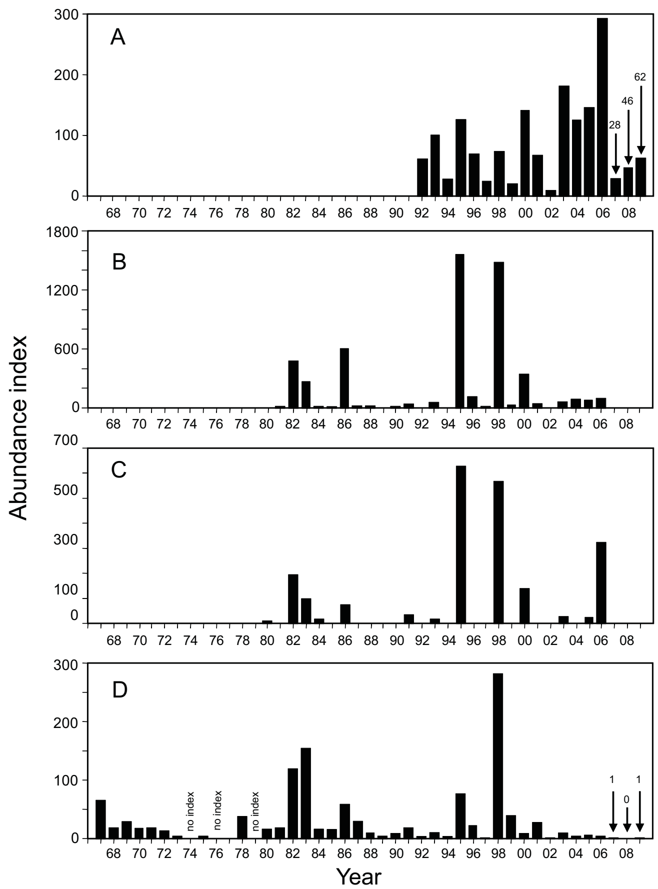

Figure 14 Annual abundance of splittail: A) USFWS beach seine, age-0, May-June; B) Bay Study midwater trawl, age-0, May-October; C) Bay Study otter trawl, age-0, May-October; D) FMWT, all sizes, September-December.

Striped bass

Striped bass (*Morone saxatilis*) is an anadromous fish first introduced to the San Francisco Estuary over 125 years ago. Adult striped bass forage in the near-shore ocean and coastal bays and migrate up rivers to spawn in spring. Juveniles rear in fresh and brackish waters of the estuary. The population of legal-size fish in the San Francisco Estuary declined from nearly 4.5 million in the early 1960s, to only 600,000 in 1994, and then increased to about 1.6 million in 2000. More recent population estimates of legal-size age-3 and older fish were about 946,000 in 2002, 829,000 in 2003, 1.3 million in 2004, 1 million in 2005, and 588,000 in 2007 (the 2004-2007 estimates are preliminary, Marty Gingras, personal communication, see “Notes”). Age-0 striped bass abundance steadily declined since the mid-1980s, and TNS and FMWT indices were generally low in the late 1990s and early 2000s when the adult population had a modest recovery. Although the adult population exhibited a modest recovery, the fraction of females in the spawning run has been very low (ca 10%) since the early or late 1990s, depending on the data set examined, and has remained low thereafter (Jason DuBois, personal communication 2008). Such low female numbers could explain the low juvenile abundance indices. Stevens et al. (1985) hypothesized that low striped bass recruitment was related to: 1) the declining adult population, 2) reduced plankton food supply, 3) loss of large numbers of young striped bass to water diversions, and 4) population-level effects of contaminants. Based on our understanding of factors controlling striped bass abundance in the estuary, the adult population increases in 2000 and 2004 were unexpected and remain unexplained.

The 2009 TNS striped bass 38.1-mm index was 0.8. This was a 27% decrease from the 2008 index and consistent with the 5 lowest indices on record for the 50 year survey (Figure 15A) since 2003. Age-0 striped bass catch peaked in late-June and declined sharply (by 57%) by early July. After mid-July, abundance continued to decrease through the end of the survey in mid-August. In June, striped bass were distributed from Suisun Bay upstream through the central and south delta, with the largest concentration found in Montezuma Slough. In July, age-0 striped bass distribution extended downstream with fish collected from Carquinez Strait to the lower Sacramento and San Joaquin rivers, the largest concentration occurring in the lower Sacramento River. In early August, the distribution contracted from Suisun Bay up to the confluence. By mid-August at the end of the survey, catch was restricted to Montezuma Slough and consisted of only 3 fish.

The 2009 FMWT age-0 striped bass index decreased to 32% of the 2008 index. This was the 2nd lowest index on record and consistent with the low indices seen since 2002 (Figure 15B). In September 2009, age-0 striped bass were caught by the midwater trawl only in Suisun Bay. In October, Suisun Bay continued to be the area with the highest catch, but in addition, they were caught in the lower Sacramento and San Joaquin rivers. October was also the month with the highest catch for the FMWT survey. By November, age-0 striped bass ranged from Carquinez Strait to the lower Sacramento River. In December, catch expanded into San Pablo Bay.

The 2009 BSMWT age-0 striped bass index declined 54% from the 2008 index and was the second lowest on record for the survey (Figure 15C). This continued the trend of very low indices since 2002 and of consistently low indices since the establishment of *C. amurensis* in 1987. In 2009, the BSMWT first collected age-0 striped bass in July and abundance peaked in July. The BSMWT sporadically collected age-0 striped bass from Suisun Bay upstream into the lower Sacramento and San Joaquin rivers.

The BSOT striped bass age-0 index for 2009 declined 67% from the 2008 level and was the fourth lowest index on record for the gear type (Figure 15D). Similar to the BSMWT, the BSOT first collected age-0 striped bass in July and abundance peaked in July. Age-0 striped bass were detected from a broad range of the upper estuary by the BSOT: eastern San Pablo Bay upstream and throughout the Sacramento and San Joaquin river stations sampled by the study. The BSOT has been more effective at catching age-0 striped bass than the BSMWT, as was observed again in 2009, when the BSOT collected 837 age-0 striped bass, while the BSMWT collected only 46 fish during the same July through December period.

The BSOT again collected greater numbers of age-0 striped bass at shoal stations than at channel stations (87% of total June through December catch in 2009; 91% in 2008). In contrast to the BSOT, only 29% of the total BSMWT age-0 catch occurred at shoal stations in 2009.

The 2009 water year was classified as dry for the Sacramento River and below normal for the San Joaquin River and similar to the two prior years' low outflows. Age-0 striped bass abundance declined in all long-term monitoring surveys. This was perhaps due to the different timing of peak outflows and more plentiful food resources for larvae in 2008 than in 2009 (April Hennessy, Figures 2 and 5, pages 15 and 16 this issue). Striped bass survival and abundance has historically showed a positive correlation to outflow, although these responses have been dampened since the invasion of the clam *C. amurensis* in the late 1980s (Kimmerer 2002, Sommer et al. 2007). Although age-0 striped bass abundance has been very low for almost 2 decades, juvenile striped bass remain more abundant in benthic shoal habitats than in channel habitats. Age-0 striped bass CPUE declined more at channel stations then shoal stations per the Bay Study otter trawl data. The mean CPUE from channel stations post-*Corbula* (1987-2008) was 9% of the mean pre-*Corbula* (1980-1986) CPUE. In comparison, the mean shoal-station post-*Corbula* CPUE was 25% of the mean pre-*Corbula* CPUE. This suggests that juvenile striped bass more successfully exploited benthic shoal habitats for food resources such as amphipods than benthic or pelagic channel habitats where the more pelagic mysids were historically abundant and a large part of their diet (Bryant and Arnold 2007, Feyrer et al. 2003). Mysids continue to be important in the young striped bass diet (Slater 2009), but now striped bass appear to have a stronger influence on mysid abundance than the other way around (Mac Nally et al. 2010)

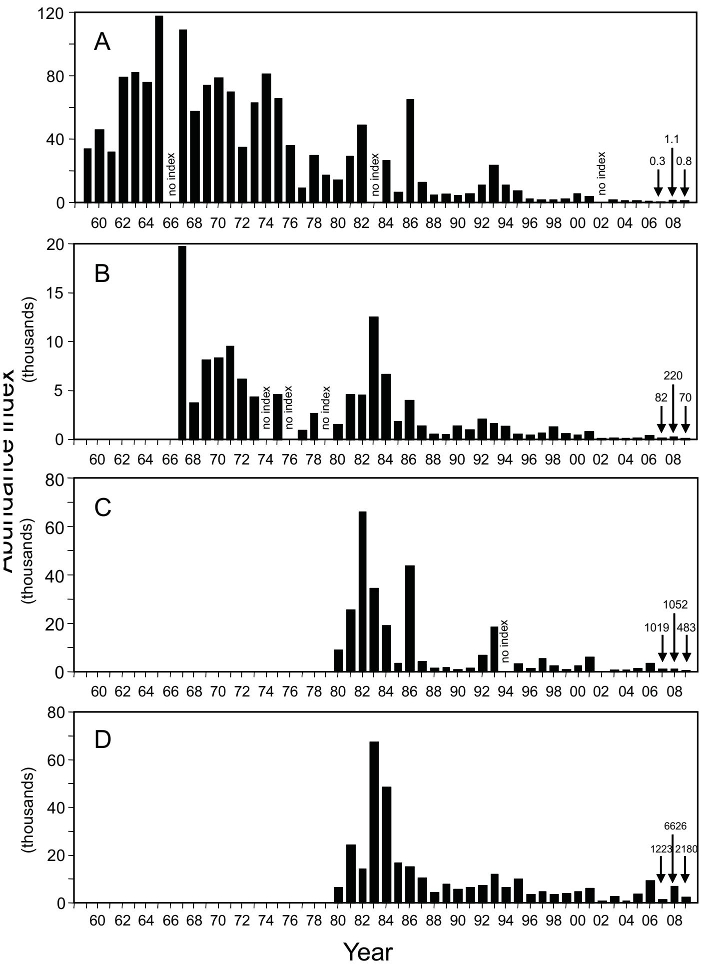

Figure 15 Annual abundance of age-0 striped bass: A) TNS 38.1-mm index; B) FMWT, September-December; C) Bay Study midwater trawl, June-October; D) Bay Study otter trawl, June-October.

Upper Estuary Demersal Fishes

Shokihaze goby

The Shokihaze goby (*Tridentiger barbatus*) is native to China, Japan, Korea, and Taiwan, and was first collected in the San Francisco Estuary by the Bay Study in 1997 (Greiner 2002). It is a short-lived species; age-1 fish spawn in brackish water during spring and early summer, and die in late summer and fall (Slater 2005). Since the Shokihaze goby is most common upstream of the Bay Study original sampling area, abundance is calculated as the annual mean catch-per-unit effort (CPUE, #/tow) for all 52 stations sampled by the otter trawl, including the lower Sacramento and San Joaquin river stations added in 1991 and 1994.

In 2009, the Shokihaze goby mean CPUE (all sizes) was 60% of the 2008 CPUE and slightly above the mean since the species' first collection (Figure 16). Shokihaze gobies were collected in all embayments except for Central Bay. They exhibited a strong association with deep-water habitat, with densities almost 15 times higher at channel stations (1.18 fish/tow) than at shoal stations (0.08 fish/tow).

Shokihaze goby densities were highest in Suisun Bay most months, but CPUE increased substantially in South Bay and the lower Sacramento and San Joaquin rivers from August to December as age-0 fish recruited to the gear. The Sacramento River channel station near lower Sherman Island was the most productive Shokihaze goby station, averaging 7.1 fish/tow for the year and reaching a maximum of 29 fish/tow in December.

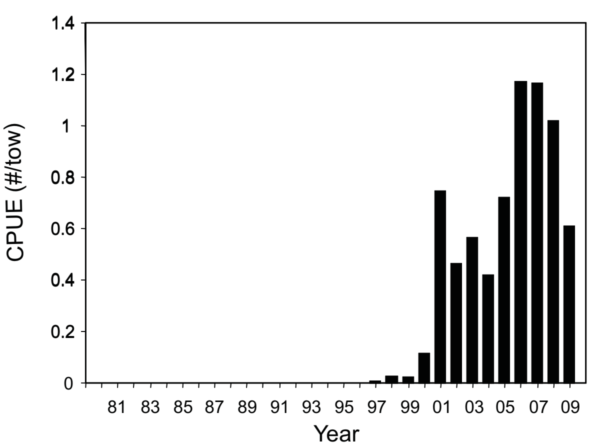

Figure 16 Annual catch-per-unit-effort (CPUE; #/tow) of Shokihaze goby (all sizes), Bay Study otter trawl, January-December.

Yellowfin goby

The yellowfin goby (*Acanthogobius flavimanus*) is an introduced fish from Asia. It is partially catadromous: adults migrate to brackish water to spawn from December through July and most die after spawning. Juvenile fish migrate upstream to lower salinity and fresh water habitats to rear through summer and fall (Moyle 2002).

The 2009 age-0 yellowfin goby abundance index declined from 2008 and was the lowest index since 1985 and the second lowest index on record (Figure 17), continuing the trend of very low indices since 2000. Age-0 yellowfin gobies first recruited to the gear in June in Suisun Bay and the lower Sacramento and San Joaquin rivers. Age-0 fish were collected from every embayment in 2009, with highest densities in Suisun Bay and the lower San Joaquin River, each averaging 0.38 fish/tow, May to December. As expected, age-0 yellowfin gobies were associated with shallow water; the CPUE for shoal stations (0.23 fish/tow) was more than double that for channels stations (0.11 fish/tow).

A total of 55 age-1+ yellowfin gobies were collected in 2009 and they occurred in every embayment. Age-1+ CPUE was highest in channels (0.31 fish/tow) during the months of December to February as mature fish migrated from Suisun Bay and the lower Sacramento and San Joaquin rivers to the lower estuary. For the remainder of the year, CPUE was highest at shoal stations (0.09 fish/ tow).

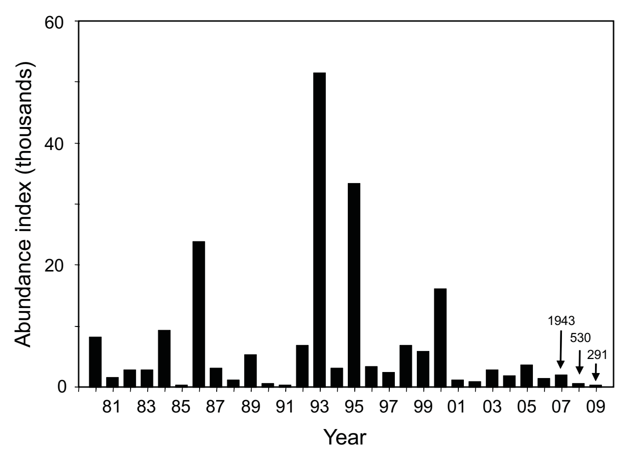

Figure 17 Annual abundance of age-0 yellowfin goby, Bay Study otter trawl, May-October.

Starry flounder

The starry flounder (*Platichthys stellatus*) is an estuary-dependent species that spawns in the ocean, but rears in brackish and fresh water areas of estuaries. In 2009, the age-0 starry flounder abundance index dropped to 30% of the 2008 index and only 13% of the study-period mean (Figure 18A). This was the lowest age-0 index since 2001. The 2009 year class first recruited to the gear in May and was collected through the end of the year.

Age-0 starry flounder were concentrated upstream of Carquinez Straight, although 1 fish was collected at a shoal station in South Bay in July. They were most common in Suisun Bay (0.4 fish/tow, May to December), followed by the lower Sacramento River and the confluence. Age-0 starry flounder were strongly associated with shallow water across all regions, from the time they were first collected through the end of the year; CPUE at shoal stations (0.18 fish/tow) was 9 times higher than at channel stations (0.02 fish/tow).

In 2009, the age-1 index dropped to 44% of the 2008 index and was only 50% of the study-period mean (Figure 18B). Age-1 starry flounder were collected from San Pablo Bay upstream in 2009 and were 20 times more abundant at shoal stations (0.23 fish/tow) than channel stations (0.01 fish/tow) all year.

The age-2+ index dropped to 27% of the 2008 index and 31% of the study-period mean (Figure 18), bringing all 3 age classes below study period mean for the first time since 2005. Most age-2+ starry flounder were collected from San Pablo Bay upstream, with 1 fish collected at the shoal station outside of Berkeley Marina. Densities were highest in Suisun Bay with catches averaging 0.19 fish/tow from January to December.

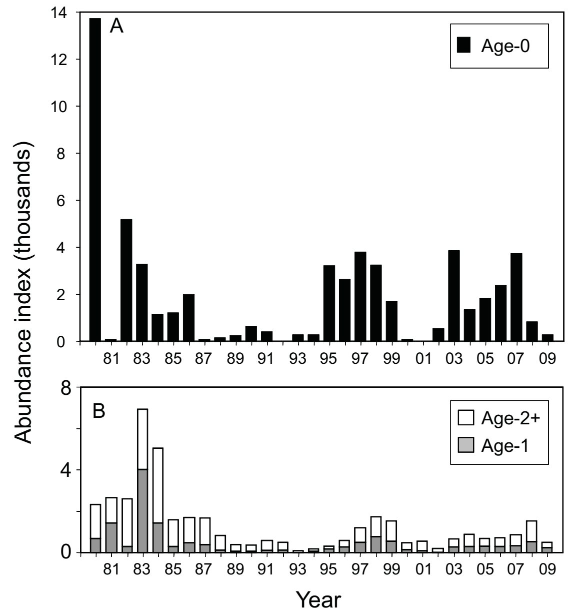

Figure 18 Annual abundance of starry flounder: A) age-0, Bay Study otter trawl, May-October, and B) age-1 and age-2+, Bay Study otter trawl, February-October.

Marine Pelagic Fishes

Pacific Herring

The Pacific herring (*Clupea pallasii*) is an estuary-dependent species that spawns and rears in higher salinity areas (>20‰) of the estuary. Spawning occurs in late winter and early spring; the adhesive eggs are deposited on substrates such as aquatic vegetation, rocks, pier pilings, and other man-made structures. After hatching and larval development, young Pacific herring remain in shallow waters and begin to school. Juveniles can be found in shallow subtidal areas and sloughs until late spring, when they migrate to deeper waters within the estuary. By fall, age-0 Pacific herring emigrate from the estuary to spend 2 to 3 years rearing in the ocean before reaching maturity and returning to spawn.

The 2009 age-0 index was less than a third of the 2008 index (Figure 19), but was nearly equal to the study-period mean. Although age-0 fish were collected all months except February, 97% of the total catch was collected between April and June, with peak abundance in May. In 2009, distribution was widest in late spring when fish were collected from South Bay to Chipps Island near the confluence of the Sacramento and San Joaquin rivers. Most age-0 fish began recruiting to the gear in March and by mid-summer had emigrated from the estuary. This emigration coincided with increased water temperatures in San Pablo and South bays. CPUE was consistently highest in Central Bay (36 fish/tow, April to December), followed by San Pablo Bay (19 fish/tow). This year's low numbers of age-0 Pacific herring may be linked to the weak year classes observed in 2005 and 2006 and the resultant low adult population spawning in 2008-2009. The California Department of Fish and Game (CDFG) Herring Project also reported low numbers of spawning age-2, age-3 and age-4 fish in this year's fishery (CDFG 2009).

The CDFG Herring Project has recorded landings for the Pacific herring fishery in San Francisco Bay since 1972. The commercial Pacific herring fishery runs from December through March, targeting adult fish entering the estuary to spawn. The 2008-2009 landings totaled 510 tons, almost 30% lower than the previous year's landings. The spawning biomass estimate of 4,844 tons for 2008-2009 was the lowest ever reported and consequently there was no herring fishery in San Francisco Bay in 2009-2010. The recent declines in San Francisco Bay herring landings and biomass may be attributed to poor environmental and biological conditions in San Francisco Bay and the ocean. Multiple years of drought have increased salinity within the bay, which in turn reduced the number of spawning events. In addition, ocean conditions were poor in 2005 and 2006, when juveniles that comprise a large number of the 2008-2009 returning adult population entered the ocean. Warmer sea surface temperatures and low ocean productivity in those years reduced fish survival, as evident by low numbers of adult fish returning in 2009.

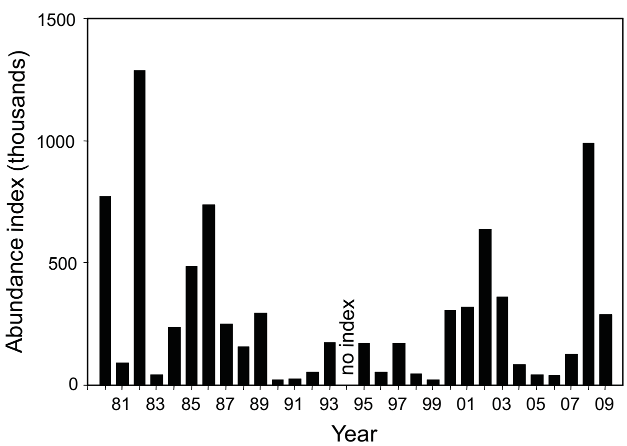

Figure 19 Annual abundance of age-0 Pacific herring, Bay Study midwater trawl, April-September.

Northern anchovy

The northern anchovy (*Engraulis mordax*) is the most common fish in the lower estuary and an important prey species for many fishes and seabirds (Bergen and Jacobson 2001). The 2009 northern anchovy abundance index (all sizes) decreased 11% from the 2008 index (Figure 20). It was the fourth lowest index on record, and only half of the study-period mean. Two-thousand nine marks the fourth consecutive year of declining indices, following the trend of colder ocean temperatures since 2006. The low 2009 anchovy abundance was linked to reproductive failure of several seabird species whose diet primarily consists of anchovies, including cormorants, seagulls and murres, and to recent seabird and sea lion deaths in San Francisco Bay. Commercial bait fishermen also reported low anchovy catches in the bay and nearshore coastal area in 2009.

Vrooman et al. (1981) separated the northern anchovy population into northern, central, and southern subpopulations. The San Francisco Estuary is situated between the northern and central subpopulations, and our catches reflect changes in the size and coastal movements of these subpopulations. Although the central subpopulation is the largest and historically the most heavily fished, there are currently no stock assessments, so we cannot confirm subpopulation movements or size from fisheries data. However, there were unpublished reports from CDFG and NMFS that northern anchovy was more common in the Southern California Bight in 2008 and 2009, leading to the conclusion that the central subpopulation shifted south with colder ocean temperatures.

Northern anchovies were collected every month in 2009, but abundance peaked in August, and was very low in January, February, November, and December. Fish were collected from South Bay near the Dumbarton Bridge to Chipps Island, just downstream of the confluence, with CPUE (April to December) highest in Central Bay (321 fish/tow), followed by San Pablo (232 fish/tow) and South (79 fish/tow) bays. Distribution shifted seasonally, with few anchovies collected in San Pablo and Suisun bays until May. Once upwelling increased in summer, CPUE in the estuary increased dramatically. In August, the highest regional CPUE was in San Pablo Bay, where catches averaged 1036 fish/tow. Anchovies used deeper waters of the estuary most months of 2009, with channel CPUE (134 fish/tow) almost twice as high as shoal CPUE (77 fish/tow).

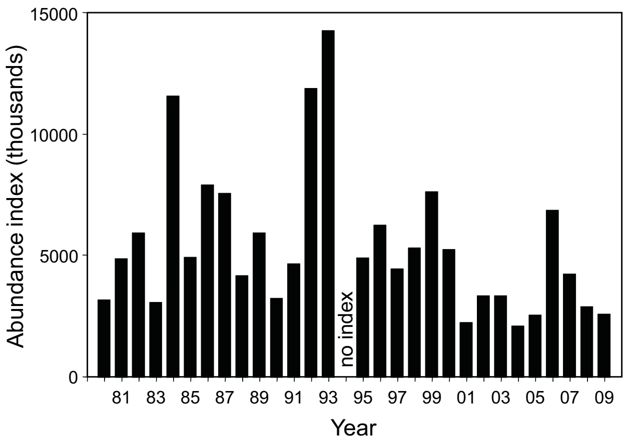

Figure 20 Annual abundance of northern anchovy (all sizes), Bay Study midwater trawl, April-October.

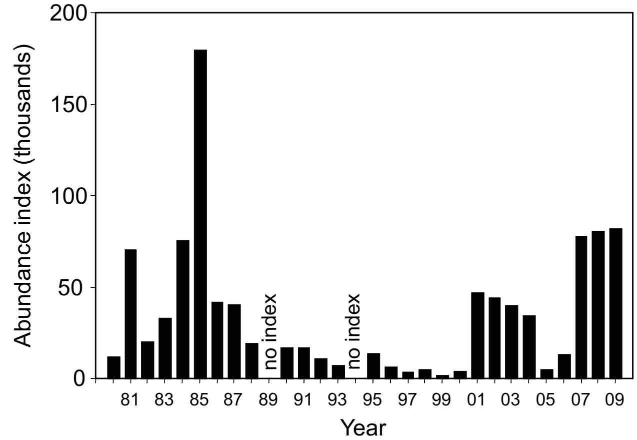

Figure 21 Annual abundance of age-0 jacksmelt, Bay Study midwater trawl, July-October.

Jacksmelt

The jacksmelt (*Atherinopsis californiensis*) seasonally migrates from nearshore coastal waters to bays and estuaries to spawn and rear. Most reproduction within the San Francisco Estuary occurs from September to April based on the presence of ripening and ripe females in San Pablo Bay (Ganssle 1966). Juvenile jacksmelt rear in shallow (<2 m) areas of South, Central, and San Pablo bays in late spring and summer. After growing to about 50 mm FL, they begin to migrate to deeper water, where they become vulnerable to the midwater trawl.

The 2009 age-0 jacksmelt abundance index was slightly higher than the 2008 index (Figure 21). It is the second highest index on record and marks the third consecutive year of above average indices. This follows the trend of increased abundance in low outflow years. In 2009, all but one age-0 jacksmelt were collected between June and October with peak abundance in July. Age-0 fish were collected from South Bay near the Dumbarton Bridge to lower San Pablo Bay, but over 50% of the total catch was caught in Central Bay. Overall, CPUE was highest in Central Bay (9.1 fish/tow, July to December), followed by South Bay (7.9 fish/tow). The high CPUE observed in South Bay can be attributed to a large catch of 237 fish in September. Seasonal movement was evident as fish were more common on the shoals in summer (9.1 fish/tow, July to September) and then moved to the channels in October (3.7 fish/tow) before emigrating from the estuary in late fall.

Surfperches

Most surfperches are transient species, migrating into bays and estuaries to give birth to live, fully-formed young in late spring and summer, and returning to the coastal ocean in fall and winter. All of the surfperches common to San Francisco Estuary underwent abundance declines in the 1980s per Bay Study trawl and sport fish survey data (DeLeón 1998). Consequently, in 2002 CDFG changed the sport fish regulations for San Francisco Bay, adopting a closed season for all surfperches, except shiner perch (*Cymatogaster aggregata*), from April 1 to July 31 and a 5-fish combination bag limit for all species except shiner perch, which was given a 20-fish bag limit.

Shiner perch

In 2009, the abundance of age-0 shiner perch (*Cymatogaster aggregata*) decreased from 2008, and was only 26% of the study period mean (Table 1). It was the lowest index since 1994. Although a few age-0 fish were collected in spring, the majority were caught between June and December. Abundance peaked in December, but was mostly driven by a large catch (68 fish) near Angel Island. Age-0 shiner perch were collected from South Bay through lower San Pablo Bay in 2009, but overall were most common in Central Bay, where CPUE averaged 1.9 fish/tow (May to December). In 2009, shiner perch were concentrated further downstream than in 2008. Some apparent seasonal movement was observed in late fall, when fish migrated from South Bay to Central Bay, and subsequently emigrated from the estuary in winter. Age-0 shiner perch were most common at shoal stations through summer and fall and shifted to the channels in December, concurrent with their migration from the estuary.

Walleye surfperch

The 2009 age-0 walleye surfperch (*Hyperprosopon argenteum*) abundance index was only 6% of the 2008 index and 13% of the study-period mean (Table 1). Only 14 age-0 walleye surfperch were collected in the MWT in 2009, all from shoal stations in southern Central and South bays. The 2009 age-1+ index was about half of the 2008 index and a third of the study-period mean (Table 1). Twenty-two age-1+ walleye surfperch were collected in the MWT during 2009 ranging from South Bay, near Oakland Airport, to lower San Pablo Bay; most came from Central Bay near Alameda. All but 1 age-1+ fish were collected from shoal stations on the eastern side of the estuary.

Other Surfperches

The 2009 barred surfperch (*Amphistichus argenteus*) abundance index for all sizes was over 3 times the 2008 index (Table 1), but was mostly driven by a large catch from a shoal station near the Oakland Airport. In 2009, the Bay Study collected 11 barred surfperch in the otter trawl, with one from a non-core station that did not contribute to the index. All fish were collected at shoal stations in Central and South bays. Historically, the majority of barred surfperch have been collected from South Bay shoal stations, especially stations along the eastern shore. Barred surfperch is commonly associated with eelgrass beds in San Francisco Bay (Merkel & Associates 2005), a habitat not sampled by our trawls.

The 2009 age-0 pile perch (*Rhacochilus vacca*) abundance index was 0, showing no sign of recovery in the estuary and continuing the trend of very low or 0 indices since 1987 (Table 1). The 2009 white seaperch (*Phanerodon furcatus*) index returned to 0 (Table 1), following a short-lived increase in 2008. One adult fish was collected in Central Bay from a non-index station in August.

Black perch (*Embiotoca jacksoni*) was the only surfperch common in the estuary that did not show a distinct decline during the late 1980s or early 1990s (Table 1). However, black perch catch has remained low relative to the most common surfperches throughout the study period. The 2009 black perch index (all ages) was based on only 1 fish collected from a shoal station near the San Mateo Bridge, and was the lowest index since 1995.

For the second year in a row, the 2009 dwarf perch (*Micrometrus minimus*) index was 0 (Table 1). One dwarf perch was collected in 2009 from a non-index shoal station in Central Bay. Historically, dwarf perch were commonly collected from shoal stations in Central and South bays. Dwarf perch is another species strongly associated with eelgrass beds in the San Francisco Bay, a habitat that is under-sampled by our trawls.

Marine Demersal Fishes

Plainfin midshipman

The plainfin midshipman (*Porichthys notatus*) migrates from coastal areas to bays and estuaries in late spring and summer to spawn. Most juveniles rear in the estuary through December, with some fish remaining until spring. The 2009 age-0 abundance index was less than 40% of the 2008 index and below the study period mean (Figure 22). The 7 highest abundance indices for the study period occurred in the past decade. Although we are not certain of the mechanism, these strong year classes were possibly associated with cool ocean temperatures. It appears likely that during the current cool water regime adult plainfin midshipman distribution has shifted southward, increasing the relative abundance of spawning stock entering the San Francisco estuary (Cloern et al. forthcoming).

Age-0 plainfin midshipmen were collected from June to December, with peak abundance in September. Age-0 midshipmen were most abundant in South Bay from June to July (0.5 fish/tow), but CPUE was highest in Central Bay for the rest of the year (12.4 fish/tow). Geographic range was widest in October, when fish were collected from South Bay to Suisun Bay, with 1 fish collected as far upstream as Sherman Island on the lower Sacramento River. Age-0 fish were more abundant at channel stations (5.0 fish/tow June to December) than shoal stations (1.3 fish/tow June to December) in 2009, and this was consistent across all embayments.

Since the late 1990s, plainfin midshipmen were collected in higher densities in Central Bay and lower densities in South and San Pablo bays. This trend persisted through various water year types and continued in 2009. The mechanism behind this apparent distributional shift is currently unexplained, but a similar increase in Central Bay CPUE was observed for other marine demersal species such as speckled sanddab (*Citharichthys stigmaeus*), bay goby (*Lepidogobius lepidus*), and English sole.

Table 1 Annual abundance indices for selected surfperch species from the Bay Study. The age-0 shiner perch, age-0 and age-1+ walleye surfperch, age-0 pile perch, and white seaperch (all sizes) indices are from May-October. The barred perch (all sizes), black perch (all sizes), and dwarf perch (all sizes) indices are from February-October.

Year	shiner perch age-0	walleye sp age-0	walleye sp age-1+	barred sp all	pile perch age-0	white seaperch all	black perch all	dwarf perch all
1980	19516	1277	642	415	857	588	0	439
1981	42760	8089	1757	691	998	1248	129	543
1982	43704	1640	992	223	471	349	54	259
1983	16147	663	135	1030	778	271	88	460
1984	14386	3846	922	502	110	873	216	50
1985	16616	362	1031	81	301	138	66	0
1986	24617	322	880	0	254	309	17	0
1987	18069	1453	2624	159	0	265	0	0
1988	7746	486	502	90	0	148	62	66
1989	6953	2046	493	109	153	48	101	97
1990	8181	516	341	105	0	95	48	26
1991	2724	22	505	75	0	0	0	15
1992	6142	443	297	27	0	0	100	0
1993	6341	617	112	29	0	0	97	0
1994	3241	no index	no index	53	0	0	125	0
1995	6661	405	269	36	0	0	0	0
1996	4404	684	380	39	0	0	225	0
1997	23896	231	643	104	0	0	231	0
1998	4384	537	911	32	75	0	65	0
1999	6237	848	2985	30	0	0	36	0
2000	4640	1229	114	29	31	0	119	0
2001	20594	8121	1003	41	0	106	248	0
2002	26131	12277	2079	76	42	260	95	0
2003	15898	2439	567	302	0	371	63	111
2004	24849	896	1438	76	0	487	253	94
2005	6225	2916	655	34	0	47	93	32
2006	4911	1610	27	46	0	0	62	34
2007	5193	248	1237	123	0	0	36	42
2008	5935	4128	529	105	0	61	69	0
2009	3408	257	289	318	0	0	26	0

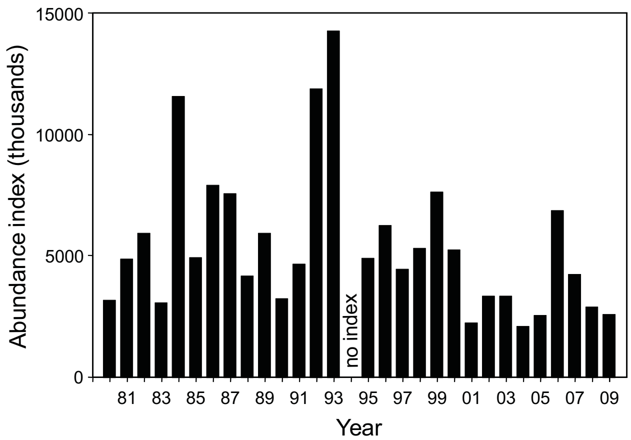

Figure 22 Annual abundance of age-0 plainfin midshipman, Bay Study otter trawl, February-October.

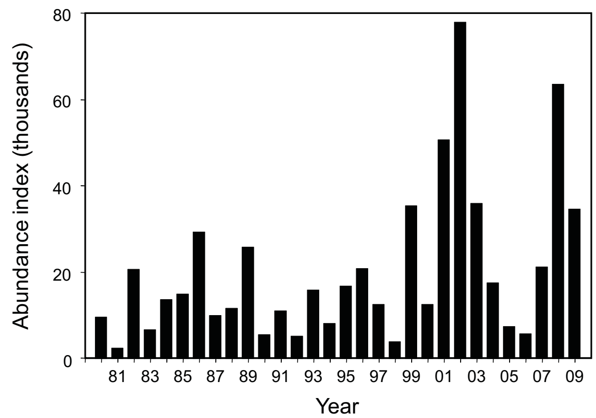

Figure 23 Annual abundance of age-0 Pacific staghorn sculpin, Bay Study otter trawl, February-September.

Pacific staghorn sculpin

The Pacific staghorn sculpin (*Leptocottus armatus*) is a common native species that usually rears in higher salinity areas, but is also found in brackish and occasionally fresh water. Throughout the estuary, it rears in intertidal and shallow subtidal areas from late winter to early spring and migrates to deeper water through summer. The 2009 staghorn sculpin age-0 abundance index was 54% of the 2008 index, but was still well above the study period mean (Figure 23). Five of the 6 highest abundance indices have occurred in the past decade, in association with cool ocean temperatures. As with other cold-temperate species, it is likely that the adult distribution has expanded southward with the recent shift in climate regime, resulting in an increase in relative abundance of spawning stock inside and surrounding the San Francisco Estuary (Cloern et al. forthcoming).

Age-0 Pacific staghorn sculpin were collected from South Bay upstream through the lower Sacramento and San Joaquin rivers adjacent to Sherman Island in 2009. Highest densities were in Central Bay, where catches averaged 8.4 fish/tow from February to September, followed by Suisun and San Pablo bays. Age-0 Pacific staghorn sculpin first recruited to the gear in February and were collected through September. Abundance was highest at shoal stations through July (3.7 fish/tow) after which distribution shifted to channel stations (5.0 fish/tow, August to September).

White croaker

The white croaker (*Genyonemus lineatus*) is a common coastal species that frequents bays and estuaries. It is a member of the subtropical fish fauna, more commonly found south of Point Conception. It spawns from November through April in shallow, nearshore waters, and juveniles progressively move into deeper water as they grow. The 2009 age-0 white croaker index was 140 times the 2008 index and the highest since 2002, but still just 20% of the study period mean (Figure 24). This year's substantial increase may be attributed to warmer sea surface temperatures in early summer 2009. Since 1995, age-0 white croaker indices have been below the study-period mean. Fish were collected throughout the year, with abundance peaking in June and again in October. In 2009, age-0 white croaker were collected from South Bay through San Pablo Bay between May and July, but by September had migrated into Central Bay. Overall, CPUE was highest in Central Bay at 1.2 fish/tow (February to December). Age-0 white croaker were more common in channels (0.57 fish/tow, February to December) than shoals (0.08 fish/tow).

The 2009 white croaker age-1+ index decreased nearly 30% from 2008 (Figure 24) and was only 15% of the study-period mean. In 2009, age-1+ fish were collected throughout the year, with no visible abundance peak. Age-1+ white croaker were collected from South Bay near Coyote Point through western Suisun Bay. Annual CPUE was highest in Central Bay (0.29 fish/tow), followed by South Bay (0.13 fish/tow). Age-1+ white croaker were more commonly caught in the channels than the shoals, with mean annual channel CPUE 3 times the shoal CPUE (0.15 vs. 0.05 fish/tow).

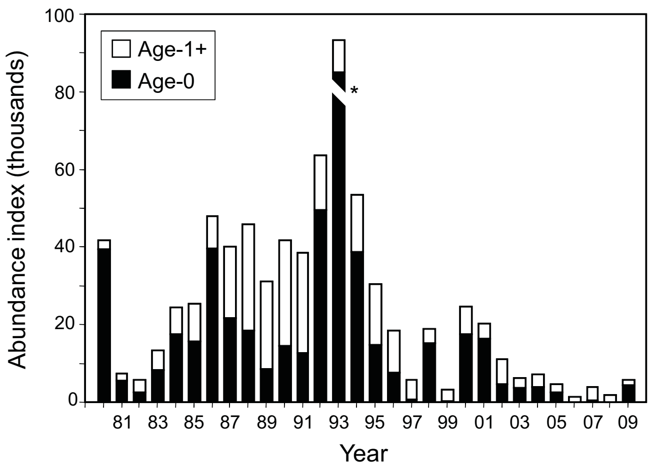

Figure 24 Annual abundance of age-0 and age-1+ white croaker, Bay Study otter trawl, February-October. The 1993 age-0 abundance index was 261,511 and has been truncated for scale considerations.

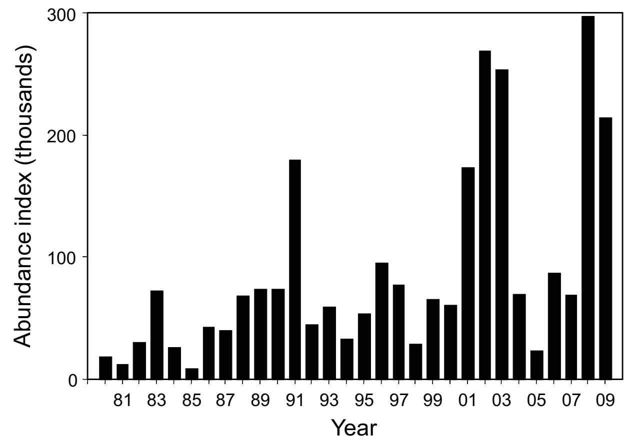

Figure 25 Annual abundance of bay goby (all sizes), Bay Study otter trawl, February-October.

Bay goby

The bay goby (*Lepidogobius lepidus*) is one of the most common gobies in the estuary. It is a native resident species that rears in the higher salinity areas and has a 2 to 3 year life span. The 2009 bay goby index (all sizes) was 72% of the 2008 index, but was the fourth highest index on record (Figure 25). Bay gobies were collected from South through Suisun bays, but were most abundant in Central Bay all months except February and April, when densities were highest in San Pablo Bay. Central Bay CPUE averaged 46 fish/tow (January to December) and peaked in June at 143 fish/tow. CPUE was highest at shoal stations from January to June and in August when small juveniles were abundant in San Pablo Bay. By mid-summer, distribution began to shift to the channels, where CPUE was consistently highest from September through the end of the year. This pattern was driven by the appearance of high densities of larger individuals in the summer months in Central Bay. These larger individuals may have moved in from near shore habitat outside of the Golden Gate or alternatively from in-bay habitats inaccessible to the trawl gear. The 2009 bay goby distribution was consistent with the long-term trend of increased Central Bay CPUE observed for plainfin midshipman and several other marine demersal species.

California halibut

The California halibut (*Paralichthys californicus)* is a member of the subtropical faunal group that became common in the San Francisco Estuary in the 1980s and 1990s, concurrent with the most recent warm-water regime. It spawns in shallow coastal waters and juveniles rear in very shallow subtidal and intertidal areas of bays and estuaries, and to a much lesser extent on the open coast. The 2009 juvenile (age-0 & 1) California halibut index was 0 for the second consecutive year (Figure 26). Three juvenile halibut were collected in non-index months of 2009 and did not contribute to the index. Two were collected in San Pablo Bay and 1 in South Bay, all from shoal stations. Continued cool ocean conditions likely limited local recruitment, exemplified by Bay Study's collection of only 5 juvenile California halibut since early 2006.

The 2009 adult (age-2+) California halibut index declined for the third consecutive year to reach the lowest level since 2004 (Figure 26). Adult fish were collected from South through San Pablo bays, but were most common in Central Bay over all months (0.14 fish/tow, January to December). Fish ranged in length from 150 mm (a juvenile) to 688 mm and most appeared to be from the large 2005-06 cohort, produced concurrent with the strongest of the recent warm-water events. Over the past several years, the publicity of the high rate of angler success and lack of other fisheries to pursue has placed considerable pressure on the San Francisco Bay California halibut fishery. This fishing pressure and associated harvest mortality has likely been a key contributor to the 2009 adult California halibut index decline.

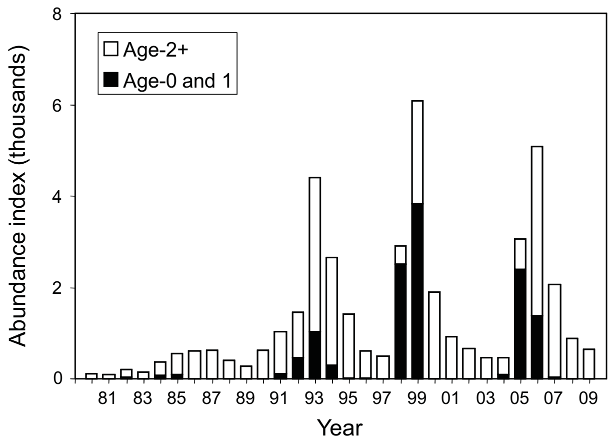

Figure 26 Annual abundance of juvenile (age-0 and age-1) and age-2+ California halibut, Bay Study otter trawl, February-October.

English sole

The English sole (*Pleuronectes vetulus*) is a common flatfish that spawns along the coast in winter and rears in both the coastal ocean and estuaries. The 2009 age-0 English sole abundance index was 88% of the 2008 index and was the third highest index on record (Figure 27). Except for 2005 and 2006, abundance was very high this decade, with the 8 highest indices for the study period occurring since 2000. It appears likely that during the current cool water regime adult English sole distribution has shifted southward, increasing the relative abundance of near shore spawning stock adjacent to the SF estuary (Cloern et al. forthcoming). In addition, cooler SSTs, weak periodic winter storms mixing subsurface nutrients with larva-bearing surface layers and strong post-settlement upwelling have likely enhanced egg and larval survival and growth.

Age-0 English sole were collected from South through Suisun bays in 2009 and were most common in Central Bay all months except January, March, and April, when highest densities occurred in San Pablo Bay. Central Bay CPUE averaged 31 fish/tow from January to December and peaked at 90 fish/tow in May. Distribution of age-0 English sole in 2009 was typical of low outflow years, with extensive immigration of very young fish in winter followed by a strong seasonal movement from South and San Pablo bays to Central Bay in late spring and from the shoals to the channels in late summer and fall. Some of the increased Central Bay channel catch in late summer was due to immigration of larger juveniles from the ocean. This aspect of the 2009 English sole distribution was consistent with the long-term trend of increased Central Bay CPUE observed for plainfin midshipman, bay goby, and several other marine demersal species.

In 2009, there appeared to be English sole from 4 distinct origins within San Francisco Estuary. From January to April at least 2 year classes were apparent, one spawned in fall 2007 (age-1+ fish), one spawned in winter 2008-2009 (age-0 fish, at least 2 cohorts), and several larger individuals, which were likely age-2+ fish migrating from nearshore costal areas. From May to July large numbers of 60-110 mm English sole appeared in Central Bay, yet proportional numbers of smaller fish were not observed in earlier surveys, which indicates that these larger juveniles entered the estuary to rear after settlement and rearing on the near-shore coast. The 2009 age-0 English sole abundance index was composed of two components: the smaller (both physically and numerically) early season group and the larger juvenile coastal migrants, though the index was dominated by the latter.

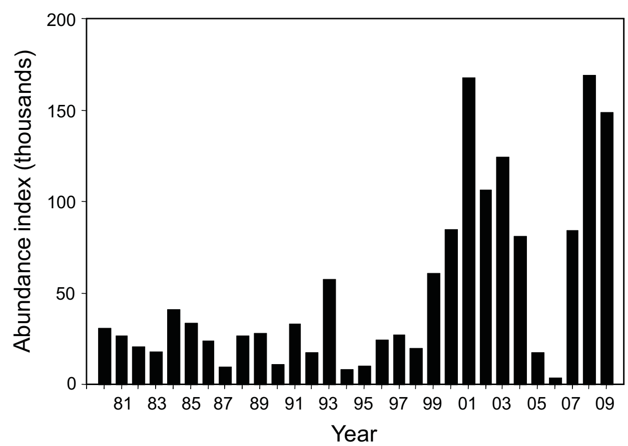

Figure 27 Annual abundance of age-0 English sole, Bay Study otter trawl, February-October.

Speckled sanddab

The speckled sanddab (*Citharichthys stigmaeus*) is one of the most abundant flatfishes in the estuary. It is a short-lived species with an estimated maximum age between 36 and 42 months. Spawning occurs along the coast and peaks in summer. In southern California, spawning is coincident with a sudden drop in bottom temperature due to upwelling (Ford 1965). Larvae may be pelagic for many months, riding ocean currents first offshore then onshore, before settling to the bottom in or near coastal and estuary rearing areas, generally in less than 40 m of water (Rackowski and Pikitch 1989, Kramer 1990).

Juveniles rear for up to a year in the estuary before immigrating to the ocean.

The 2009 speckled sanddab abundance index (all sizes) was slightly higher than the 2008 index and just above the study period mean (Figure 28). After 4 very high indices in the early 2000s, abundance dropped substantially, and then has remained relatively stable since 2005. The 2009 index was composed primarily of fish from 2 year classes: the 2008 year class that hatched in summer 2008 and the larger 2009 year class that hatched in summer 2009. Abundance peaked in December; these were fish that hatched and settled in 2009, not 2008. Distribution ranged from South Bay to Suisun Bay but densities were highest in Central Bay all months. Over 90% of the 2009 speckled sanddab otter trawl catch came from Central Bay stations. CPUE was higher at channel stations (7.7 fish/tow) than shoal stations (3.3 fish/tow) for the entire year. The 2009 speckled sanddab distribution was consistent with the long-term trend of increased Central Bay CPUE also observed for plainfin midshipman, bay goby, English sole, and several other marine demersal species.

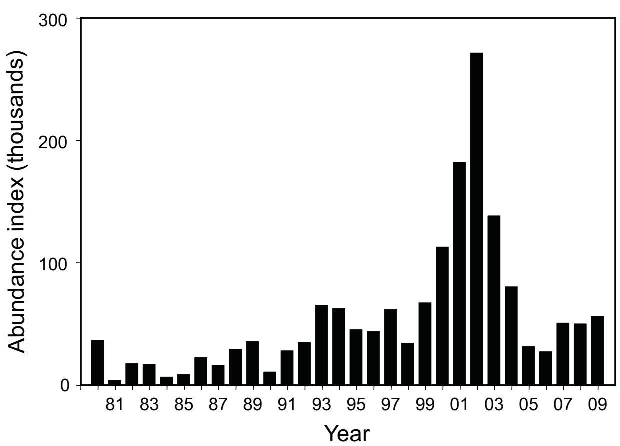

Figure 28 Annual abundance of speckled sanddab (all sizes), Bay Study otter trawl, February-October.

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- 20-mm Survey, Julio Adib-Samii (jadibsamii@dfg.ca.gov).

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Notes

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Marty Gingras, California Department of Fish and Game, email June 29, 2009.

Jason DuBois, California Department of Fish and Game, email October 3, 2008.

Fish Salvage at the State Water Project's and Central Valley Project's Fish Facilities during 2009

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Introduction

Two facilities reduce the fish loss associated with water export by the federal Central Valley Project (CVP) and California's State Water Project (SWP). The CVP's Tracy Fish Collection Facility (TFCF) and the SWP's Skinner Delta Fish Protective Facility (SDFPF) divert (salvage) fish from water exported from the southern end of the Sacramento-San Joaquin Delta. Both facilities use louver-bypass systems to remove fish from the exported water. The diverted fish are periodically loaded into tanker trucks, transported to fixed release sites, and returned to the western Delta. The TFCF began operations in 1957. Operations at the SDFPF began in 1967.

This report summarizes the 2009 salvage information from the TFCF and the SDFPF, and discusses data from 1982 to 2009 for its relevance to recent conditions. The following species are given individual consideration: Chinook salmon (*Oncorhynchus tshawytscha*), steelhead (*O. mykiss*), striped bass[1] (*Morone saxatilis*), delta smelt[1] (*Hypomesus transpacificus*), longfin smelt[1] (*Spirinchus thaleichthys*), threadfin shad[1] (*Dorosoma petenense*), and splittail (*Pogonichthys macrolepidotus*).

Systematic sampling was used to estimate the numbers and species of fish salvaged at both facilities. Bypass flows into the fish-collection buildings were sub-sampled once every 2 hours for 10 to 30 minutes. Fish 20 mm (fork length: FL) or larger from the sub-sampled bypass flows were identified and numerated. These fish counts were expanded (based on sub-sample duration: sub-sample 10 minutes of 120 minutes = expansion factor of 12) to estimate the total number of fish salvaged in each 2-hour period of water export. These incremental salvage estimates were then summed across time to develop monthly and annual species-salvage totals for each facility.

Chinook salmon loss estimates are presented because the loss model has been widely accepted and has undergone extensive field validation. Loss is the estimated number of fish entrained by the facility minus the number

1. Pelagic Organism Decline (POD) species

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